In-Situ Resource Utilization: Methane Fuel Production (ISRU)

Completed Technology Project (2017 - 2018)

Project Introduction

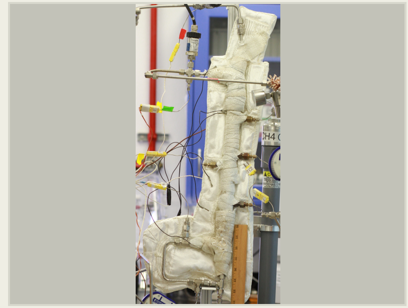
Sabatier reactors are being matured to produce methane from CO_2 and hydrogen. The hydrogen is derived from the electrolysis of soil-derived water, and the CO_2 is derived from the Mars atmosphere. A Sabatier system has been in use on the International Space Station (ISS) for some years so there is a high level of confidence in the technology, but In Situ Resource Utilization (ISRU) methane production requirements are much larger than the current ISS reactors. These reactors are exothermic catalyst-based systems that require thermal and flow management and post-reactor gas separation. The ISRU Technology project is working challenges related to scaling up the reactor size, proper start-up and shutdown sequences, and the health and lifetime of the catalyst.

Methane Fuel Production is part of the AES In-Situ Resource Utilization (ISRU) Technology Project which is developing the component, subsystem, and system technology to enable production of mission consumables from regolith and atmospheric resources at a variety of destinations for future human exploration missions.

The overall goals of the ISRU Technology project are to achieve system-level TRL 6 to support future flight demonstration missions and provide exploration architecture teams with validated, high-fidelity answers for mass, power, and volume of ISRU systems.

The project's initial focus is on critical technology gap closure and component development in a relevant environment (TRL 5) for Resource Acquisition (excavation, drilling, atmosphere collection, and preparation/beneficiation before processing) and Resource Processing & Consumable Production (extraction and processing of resources into products with immediate use as propellants, life support gases, fuel cell reactants, and feedstock for construction and manufacturing). The interim project goal is to complete ISRU subsystem tests in a relevant environment to advance the subsystem to TRL 6. The project end goals are to perform end-to-end ISRU system tests in a relevant environment (system TRL 6) and integrated ISRU-exploration elements demonstrations in a relevant environment.

ISRU is a disruptive capability that enables more affordable exploration than today's paradigm where all supplies are brought from Earth, and allows more sustainable architectures to be developed. The availability of ISRU technologies can radically change the mission architecture and be the sizing design driver for other complex systems already in development. For example, the current Mars architecture assumes ISRU production of up to 30 metric tons of propellant on the Mars surface in order to reduce the ascent vehicle landed mass by 75 percent and reduce Earth launch needs by at least 300 metric tons. If a decision was made to use storable propellants for the Mars ascent vehicle instead of ISRU-producible oxygen and methane, many other drastic changes to the architecture could be required, such as lander and



Sabatier reactor installed in test stand (some insulation removed for viewing)

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ascent vehicle size, number of landers needed, surface operations for ascent vehicle fueling, and Mars rendezvous orbit. Other surface systems might become more complex or heavier if they are not designed to take full advantage of ISRU technologies. Examples include a more complex closed-loop life support system if resupply with ISRU water cannot be assumed, or a heavy, built-in habitat radiation shield if a water- or regolith-based shield cannot be added after habitat delivery to the surface.

Other system designers may also make decisions that reduce the benefit of incorporating ISRU into the mission, resulting in a larger or more inefficient ISRU system. For example, a non-continuous power source such as solar power would increase the required production rate and peak power of an ISRU plant, thus increasing its size and complexity due to hundreds of start-stop cycles. However, a continuous power source, such as nuclear or solar power with storage, would allow an ISRU plant to operate continuously, thus minimizing its size, complexity, and power draw. These are only a few examples of how the inclusion of ISRU has ripple effects across many other exploration elements.

ISRU is also a new capability that has never before been demonstrated in space or on another extraterrestrial body. Every other exploration system or element, such as power, propulsion, habitats, landers, life support, rovers, etc., have some form of flight heritage, although almost all still need technology development to achieve the objectives of future missions. This is another critical reason why ISRU technology development, leading to a flight demonstration mission, needs to be started now, so that flight demonstration results can be obtained early enough to ensure that lessons learned can be incorporated into the final design.

This technology development activity was transferred to the STMD Game Changing Development Program in October 2018.

Anticipated Benefits

This technology is categorized as a prototype hardware system for manned spaceflight.

Methane fuel is produced from carbon dioxide derived from Mars atmosphere and hydrogen derived from electrolysis of soil-derived water. Methane fuel is combined with oxygen to provide propellant for ascent vehicles and Earth return vehicles.   This capability can significantly reduce mission launch mass, lander size and/or number needed, reduce ascent vehicle size and/or increase rendezvous orbit, and enable or enhance mission capabilities.

Organizational Responsibility

Responsible Mission Directorate:

Exploration Systems Development Mission Directorate (ESDMD)

Lead Center / Facility:

Glenn Research Center (GRC)

Responsible Program:

Exploration Capabilities

Project Management

Program Director:

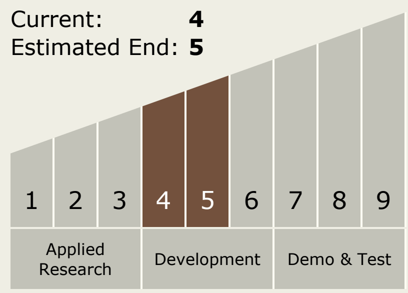
Christopher L Moore

Project Managers:

Diane L Linne
Gerald B Sanders

Technology Maturity (TRL)

Start: **4**
Current: **4**
Estimated End: **5**



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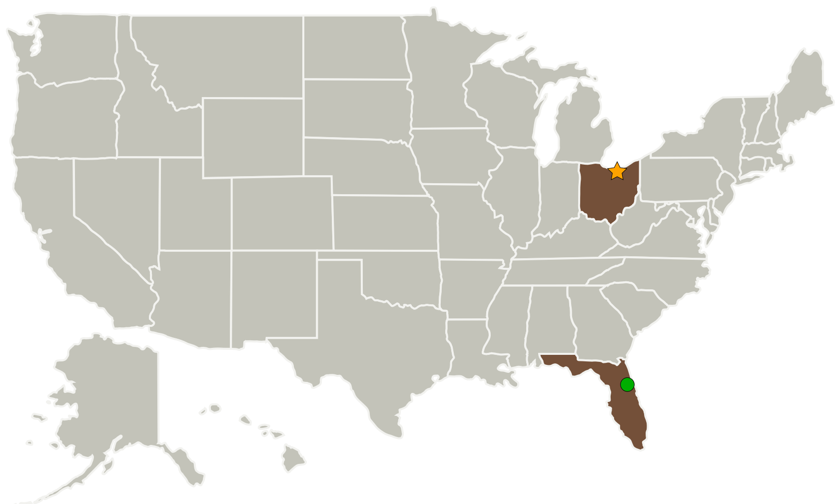
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★Glenn Research Center(GRC)	Lead Organization	NASA Center	Cleveland, Ohio
●Kennedy Space Center(KSC)	Supporting Organization	NASA Center	Kennedy Space Center, Florida

Primary U.S. Work Locations	
Florida	Ohio

Project Transitions

October 2017: Project Start

September 2018: Closed out

Closeout Summary: This AES project was transferred to the NASA Space Tech nology Mission Directorate (STMD) as of October 2020.

Technology Areas

Primary:

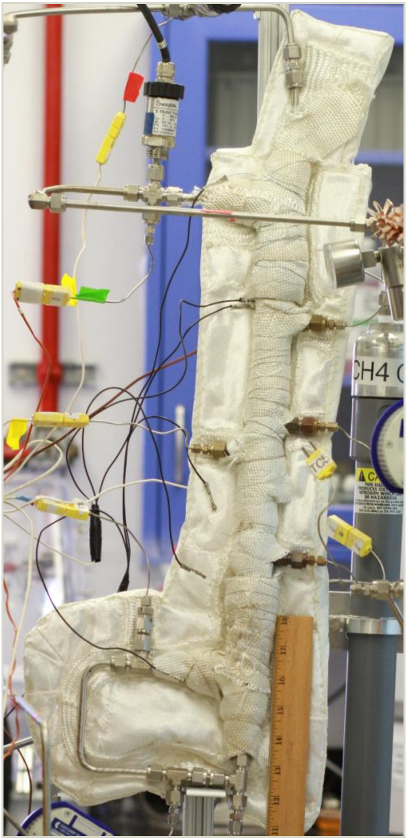
- TX07 Exploration Destination Systems
  - └ TX07.1 In-Situ Resource Utilization
    - └ TX07.1.3 Resource Processing for Production of Mission Consumables

Target Destinations

The Moon, Mars, Others Inside the Solar System

Images

Sabatier reactor CAD
CAD rendering of Sabatier test hardware
(https://techport.nasa.gov/image/38008)



Sabatier reactor hardware
Sabatier reactor installed in test stand (some insulation removed for viewing)
(https://techport.nasa.gov/image/38007)